Supporting Air Traffic Flow Management with Agents

Shawn R. Wolfe

Intelligent Systems Division
NASA Ames Research Center
Moffett Field, CA 94035-1000
Shawn.R.Wolfe@nasa.gov

Abstract

Air traffic flow management is an inherently complex decision making process that involves a variety of entities. We propose an agent-based system to facilitate mutually beneficial air traffic management decisions, and identify challenges that must be met for its implementation.

Introduction

Airline flights follow predefined traffic streams that are limited in the number of simultaneous flights they can safely accommodate. When the air stream capacity drops below the demand (e.g., due to weather) or when traffic exceeds the capacity, air traffic controllers must reduce the traffic on the impacted stream to acceptable levels. Air traffic flow management, therefore, involves careful planning and re-planning, requiring controllers to react and anticipate developments in a dynamic system in order to keep traffic flowing without compromising safety.

Current State of Traffic Flow Management

The Air Traffic Control System Command Center (ATCSCC) controls the traffic flow in the airspace over the continental United States, which is further subdivided into twenty disjoint regions, each under the control of an Air Traffic Control Center (ARTCC). Each ARTCC has a Traffic Management Unit (TMU) that is responsible for directing airline flights through the airspace between the departure and arrival airports. Each airline has an airline operation center (AOC) which coordinates with the TMU, representing the airline in the traffic management process. Under ideal conditions the TMU would be able to safely redirect traffic while minimizing traffic disruptions and maximizing airline satisfaction. However, a lack of planning and impact assessment tools, limited coordination with the airlines, and overall high workload interfere with the TMU's ability to make optimal decisions. As a result, the TMU often chooses mitigating actions aimed at maintaining safety and simplifying the management task, but at the cost of more efficient airline operations.

Distributed Air/Ground Traffic Management

Airline traffic is expected to triple by 2025, which would exacerbate traffic congestion problems under the existing traffic management system. Responding to these projections, NASA developed the Distributed Air/Ground Traffic Management (DAG-TM) (NASA 1999) concept of operations. This concept of operations was refined through extensive field observations and interviews at a busy ARTCC and corresponding AOC (Idris et al. 2006). Though the concept of operations recommends a variety of changes to the current system, we focus on the recommendation to enhance coordination between the TMU and the AOC, noting that much of traffic management is a collaborative decision making process.

Agents in Air Traffic Flow Management

Air traffic controllers and airline personnel are limited resources in air traffic management. To compensate for their scarcity, intelligent agents can be employed both in simulations (replacing human operators) and in actual operations (assisting their human counterparts).

Validating the Concept of Operations

As in any critical system, changes to the air traffic system should be validated before deployment. In aviation, this usually starts with a "fast-time" simulation, where humans are simulated with automation. These automated stand-ins are replaced by human operators in limited trial deployments, and if these are successful, the concept or operations is ready for widespread deployment.

The DAG-TM concept of operations includes assistive agents who work with their human counterparts. As such, a fast-time simulation would involve both stand-in software agents and these assistive agents. Stand-in agents that are particularly adept at their role could lead to changes in the concept of operations: tasks originally planned for humans could be delegated to such agents.

Assistive Agents in Operations

The DAG-TM recommendations favor enhancing communications rather than enhancing the tool-set. The current modes of communication between the TMU and AOC are primarily synchronous (e.g., teleconferences). However, the demands of operating in a real-time environment are significant and preclude spending a great deal of time in communications, resulting in a loss of efficiency.

Assistive agents can handle portions of this communication process, enabling less intrusive, asynchronous forms of communication or even automating some negotiations entirely. Agents can broadcast information (e.g., airspace demand, impact assessments, scheduling decisions) to cooperating parties, distilling and presenting information to the user. They can act as a proxy for the user, presenting policy or preference information, or take their place in negotiation. Finally, when appropriate, they can assist the user in decision-making, or be granted the authority to make certain decisions without human involvement.

Open Issues

Agents show great potential to facilitate more efficient air traffic management, but a variety of challenges must be met for their successful deployment.

Supporting Communication

Our primary focus is to facilitate better coordination between the TMU and the AOC through more effective communication. Time constraints prevent the users from addressing this themselves; agents do not face the same restrictions, but present different challenges.

Modeling Users and Preferences. An excellent understanding of the involved entities, both organizations and individuals, will be required to create effective assistive agents and accurate fast-time simulations. That representation should be easily understood yet powerful enough to capture business models, environmental constraints and user intents. Are the processes and behaviors of by humans sufficiently understood so that they can be emulated by agents in the fast-time simulation?

Effective Communication Modes. The alternative forms of communication must be carefully considered for each information transaction. Under what circumstances is a static policy (i.e., preferences) sufficient? How and when is it appropriate to notify or interrupt a user?

Information Integration, Translation & Interpretation. A user's agent must be able to combine, refine, and filter communicated information in order to reduce the user's cognitive overhead. This requires an understanding and mediation of the different languages used by the different entities involved – concepts used by one agent will relate but not exactly match that of another; different parties may use different terminology and approach traffic management differently. The agent must use reasoning to re-express information in terms that are best understood by the user.

Delegation and Shared Control

Field observations indicated that high TMU workload inhibited the communication needed to support optimal decisions. Agents can reduce this workload by sharing the task burden.

Full Autonomy. Any task that can be completely automated offers the greatest gain to the offloaded user, but care must be taken when automating critical actions. What tasks can the agent perform independently without jeopardizing safety, and how can this be demonstrated?

Mixed Initiative. Other tasks may be completed by the user alone, the agent alone, or jointly. Though often safer than pure autonomy, shared activities have other control issues. Cooperation is more complex than independent activity and the agent must not counteract user actions.

Knowledge Acquisition

Implementing and adapting a system of agents for air traffic management will be knowledge intensive. Some of this knowledge can be elicited from experts, but this is not always practical, and some knowledge is difficult even for experts to articulate or realize.

Learning from Historical Data. When available, historical data can serve as a basis for developing models of human behavior, either manually or through machine learning methods. Environmental conditions and inputs from other persons form the attribute space, from which the correct decision could be learned.

Adapting to Changing Conditions. Just as learning can be used to set up the initial model, it can also be used by the agent to adapt to the simulation. This gives the agent the ability to both adapt to situations different than in the historical data as well as to correct errors in its model.

Conclusion

Today's air traffic management system is a high-stakes, complex system that has maintained a remarkable safety record. Part of this safety record has come at the cost of increased delays, a trend that is expected to increase in the future. Assistive agents can help reverse this trend by supporting better communication between collaborating parties, thus leading to improved decisions. However, several technical obstacles must be overcome for such agents to be effective: supporting minimal and effective communication; sharing control; and building and refining models based on historical data and experience.

References

Idris, H., Evans, A., Vivona, R., Krozel, J., and Bilimoria, K. 2006. Field Observations of Interactions between Traffic Flow Management and Airline Operations. In *Proceedings of the AIAA 6th Aviation, Technology, Integration, and Operations Conference (ATIO)*, Wichita, Kansas.

NASA, 1999. Concept Definition for Distributed Air/Ground Traffic Management (DAG-TM). v1.0. NASA Ames Research Center, Moffett Field.